

U.S. ARMY

**Center for
Army
Analysis**

ANALYSIS OF COMPLEX THREATS II

JUNE 2001



**DISTRIBUTION STATEMENT A:
Approved for Public Release -
Distribution Unlimited**

**CENTER FOR ARMY ANALYSIS
6001 GOETHALS ROAD
FORT BELVOIR, VA 22060-5230**

DISCLAIMER

The findings of this report are not to be construed as an official Department of the Army position, policy, or decision unless so designated by other official documentation. Comments or suggestions should be addressed to:

**Director
Center for Army Analysis
ATTN: CSCA-RA
6001 Goethals Road
Fort Belvoir, VA 22060-5230**

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 074-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE June 2001	3. REPORT TYPE AND DATES COVERED Final, September 2000 – June 2001		
4. TITLE AND SUBTITLE Analysis of Complex Threats II (ACT II)		5. FUNDING NUMBER		
6. AUTHOR(S) Dr. Sean O'Brien				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for Army Analysis 6001 Goethals Road Fort Belvoir, VA 22060-5230		8. PERFORMING ORGANIZATION REPORT NUMBER CAA-R-01-41		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Deputy Chief of Staff for Operations and Plans ATTN: DAMO-SSW 400 Army Pentagon Washington, DC 20310-0400		10. SPONSORING / MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES Second addressee: Deputy Chief of Staff for Intelligence, ATTN: DAMI-ZA, 1000 Army Pentagon, Washington, DC 20310-1000				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; dissemination unlimited		12b. DISTRIBUTION CODE A		
13. ABSTRACT (Maximum 200 Words) This study was undertaken to develop and validate an approach or methodology to forecast country and regional instabilities over the period 2010 through 2015. During the process, the Center for Army Analysis was to broaden the scope of the country instability analysis reported in an earlier CAA report, Analysis of Complex Threats (ACT), CAA-R-99-4, to include additional independent and dependent variables. Another requirement was to continue exploration, application, development, and refinement of analytical tools to explore the relationship between country macro-structural conditions and country instability.				
14. SUBJECT TERMS Country instability, forecasting methodology			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	

20020220 096

CAA-R-01-41

(THIS PAGE INTENTIONALLY LEFT BLANK)

ANALYSIS OF COMPLEX THREATS II

SUMMARY

THE PROJECT PURPOSE was to deepen and extend the methodology developed in *Analysis of Complex Threats (ACT)* (CAA-SR-99-4) in order to validate a 15-year forecast of country instability.

THIS PROJECT WAS COSPONSORED by the Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS), War Plans Division, and the Office of the Deputy Chief of Staff for Intelligence (ODCSINT), Headquarters, Department of the Army.

THE SCOPE OF THE PROJECT was to:

- (1) Broaden the scope of the country instability analysis first conducted in the ACT study to include additional dependent and independent variables;
- (2) Continue the examination of available analytical methods as well as the development and refinement of new methods for forecasting country instability;
- (3) Conduct and validate a 15-year forecast of country instability.

THE BASIC APPROACH for this project was to

- (1) Expand the temporal domain of the ACT database from 1989-1997 to 1960-1999 in order to provide sufficient historical data to validate a long-term forecast of country instability;
- (2) Add additional macro-structural indicators to the database including levels of democracy, global trade, average life expectancy, and religious and ethnic diversity;
- (3) Add a dependent variable to the database that tracks both violent and nonviolent intra- and interstate conflicts that have occurred over the period 1945-1999;
- (4) Refine the Fuzzy Analysis of Statistical Evidence (FASE) methodology, first used in ACT, to predict various levels of intensity of country instability.

THE PRINCIPAL FINDINGS are that:

- (1) A new dependent variable was successfully incorporated into the approach to allow for forecasting different levels of intensity of country instability.
- (2) The approach was broadened to include additional independent variables, measuring religious and ethnic diversity, quality of public health systems, international trade relationships, and commitments to political rights.

(3) The new FASE methodology demonstrated the capability to validate a global, 15-year forecast of country instability at about 75 percent overall accuracy.

THE PROJECT EFFORT was conducted by Dr. Sean P. O'Brien, Resource Analysis Division, Center for Army Analysis (CAA).

COMMENTS AND QUESTIONS may be sent to the Director, Center for Army Analysis, ATTN: CSCA-RA, 6001 Goethals Road, Suite 102, Fort Belvoir, VA 22060-5230.

CONTENTS**Page**

1	ANALYSIS OF COMPLEX THREATS II.....	1
1.1	Introduction.....	1
1.2	Purpose.....	1
1.3	ACT II Enhancements	2
1.4	Original ACT Study Data	4
1.5	Data Added for ACT II.....	5
1.6	Expanding the Definition of Instability	6
1.7	Three Levels of Instability Intensity	8
1.8	Forecasting Method.....	9
1.9	Enhancements Made to FASE Model for ACT II.....	10
1.10	FASE: Possibility Aggregation Example.....	11
1.11	Model Development, Training, and Validation	13
1.12	Model Development, Training, and Validation - Colombia	14
1.13	Model Development, Training, and Validation - Kyrgyzstan	15
1.14	5- to 15-Year Validation of FASE Model.....	16
1.15	15-Year Validation of FASE Model	17
1.16	Summary.....	18
	APPENDIX A PROJECT CONTRIBUTORS	A-1
	APPENDIX B REQUEST FOR ANALYTICAL SUPPORT.....	B-1

FIGURES

Figure 1.	Purpose	1
Figure 2.	ACT II Enhancements	3
Figure 3.	Original ACT Study Data	4
Figure 4.	Data Added for ACT II.....	5
Figure 5.	Expanding the Definition of Instability	6
Figure 6.	Three Levels of Instability Intensity.....	8
Figure 7.	Forecasting Method	9
Figure 8.	Enhancements Made to FASE Model for ACT II.....	10
Figure 9.	FASE: Possibility Aggregation Example	11
Figure 10.	Model Development, Training, and Validation.....	13
Figure 11.	Model Development, Training, and Validation - Colombia.....	14
Figure 12.	Model Development, Training, and Validation - Kyrgyzstan.....	15
Figure 13.	5- to 15-Year Validation of FASE Model	16
Figure 14.	15-Year Validation of FASE Model.....	17
Figure 15.	Summary.....	18

(THIS PAGE INTENTIONALLY LEFT BLANK)

1 ANALYSIS OF COMPLEX THREATS II

1.1 Introduction

This project, *Analysis of Complex Threats II (ACT II)*, was co-sponsored by the Headquarters, Department of the Army (HQDA) Deputy Chief of Staff for Operations and Plans (DCSOPS) and the Deputy Chief of Staff for Intelligence (DCSINT).

1.2 Purpose

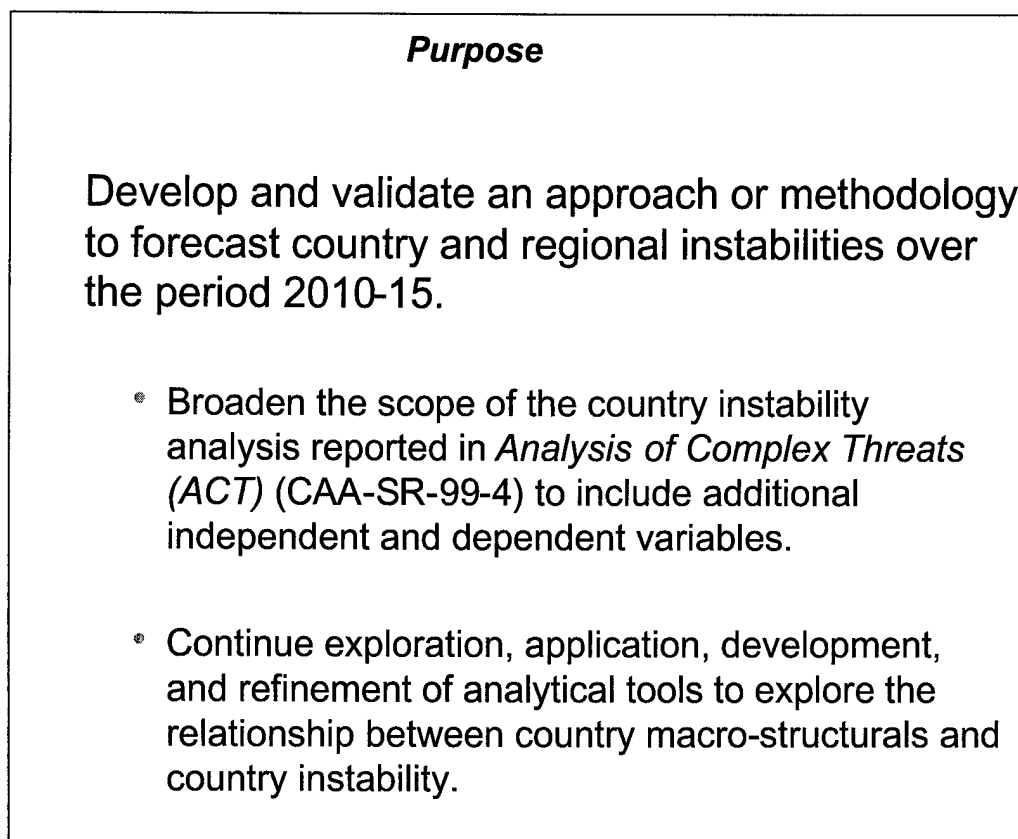


Figure 1. Purpose

In November 1997, the Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS), War Plans Division, asked the Center for Army Analysis (CAA) to develop and demonstrate a methodology to forecast the likelihood that some nonspecific level of instability could occur in any given country over a 5-year period that might challenge US national security interests and precipitate smaller-scale contingency (SSC) deployments by the Army. The War Plans Division wanted an analytically defensible approach for supporting the development and

evaluation of long-range scenarios in which the Army may be deployed to defend and support US national security interests in the future. This initial work was completed by CAA in May 2000 and is described in the report, *Analysis of Complex Threats (ACT)*.

The ACT Study first drew upon several prior CAA studies to identify key structural factors that could contribute to the stability (or instability) of a country. A country's gross domestic product (GDP) per capita, infant mortality rate, position on a political rights index, youth bulge, and daily caloric consumption per person per day were the internal country factors used in ACT analytical models. The relationship between these factors and historical instances of country instability was explored and modeled using traditional machine learning and data mining techniques in addition to more recently developed statistical, fuzzy, and temporal data mining techniques. For the purpose of validating the models, country instability was reflected by "armed conflicts involving at least 25 battle-related deaths" that occurred between 1989 and 1997. The forecasting capabilities of ACT were validated and tested for global and regional models with good performance results over a 5-year period of time.

At the request of the Office of the Deputy Chief of Staff for Intelligence (ODCSINT), the ACT study was briefed to LTG Kennedy on 13 May 1999. LTG Kennedy asked CAA to further develop and improve ACT. Specifically, LTG Kennedy requested that CAA consider adding factors to the model, such as ethnic/religious diversity and environmental factors, continue to develop new analytical tools and techniques, and broaden the definition of instability to include both violent and nonviolent (but still serious) events that characterize country instability. The *Analysis of Complex Threats II (ACT II)* study, presented in this report, evolved from this tasking. On 27 May 1999, MG St. Onge agreed to cosponsor ACT II with the ODSCINT.

1.3 ACT II Enhancements

Figure 2 describes the enhancements that were made to the country instability forecasting approach in ACT II in comparison to the level of sophistication achieved in ACT. These include the following:

- ACT possessed the capability to forecast the likelihood that *an* instability would occur in any given country over a 2- through 5- year period with about 70 percent accuracy. Currently, ACT II provides the capability to forecast not just the likelihood that an instability will occur, but also that that instability will occur within a certain range or level of intensity (e.g., low, moderate, or high). Despite this greater specificity on the element of prediction, it proved possible in ACT II to validate a 15-year forecast at about 75 percent accuracy.
- Several factors (e.g., contributors to instability or independent variables) were added to the ACT database. These included information on a country's commitment to civil liberties, level of democracy, commitment to rules of global trade, its ethnic and religious diversity, and its peoples' average life expectancy.
- The ACT database contained annualized data for every major country over the 9-year period 1989-1997. In order to accommodate the need to validate a 15-year forecast, the temporal frame of the database had to be deepened; currently, the ACT II database covers the period 1960-1999.

ACT II Enhancements

	ACT	ACT II
Element of prediction	Likelihood of country instability	Likelihood that country will experience a certain level of intensity of instability
Validation forecast horizon	2 - 5 years out	15 years out.
Temporal domain of historical database	1989 - 1997	1960 - 1999
Macro-structural indicators	5 - 7 (depending on analytical technique used)	12
Proxy indicator of instability (dependent variable)	Violent, armed conflict that results in battle fatalities	Violent and nonviolent crises and wars that may or may not involve battle-related fatalities

Figure 2. ACT II Enhancements

- Finally, the definition of *instability* and therefore the scope of the study was expanded to include both violent and nonviolent but still serious types of wars and state crises. It is prudent to consider within an early warning framework, both violent and nonviolent conflicts because, short of complete conflict prevention, it is the prevention of that *escalation* from nonviolent crisis to war that one hopes to accomplish with some advanced warning. The inclusion of violent and nonviolent events of varying degrees of intensity also facilitates the creation of a proxy index of instability which is used in this study as the basis from which to generate estimates of the likelihood of different levels of intensity of country instability.

1.4 Original ACT Study Data

Figures 3 and 4 describe the 12 macro-structural factors--potential contributors to instability--used in ACT II to validate a 15-year forecast. The six macro-structural indicators in Figure 3 were used in the ACT study; the six factors in Figure 4 have since been added to the database for use in ACT II analyses. Data were collected for each of these 12 factors on an annual basis for every major country over the period 1960-1999. Generally, however, only data for the period 1975-1999 are used to validate the 15-year forecast. This temporal restriction was imposed for two reasons. First, in general, the quality and consistency of the data degrades the further one goes back in time. Second, recognizing that the nature and causes of intra- and interstate conflict have probably evolved over time, it seemed prudent to ensure that an analysis of conflict in and around the post-Cold War era (and well beyond to 2015) was not unduly influenced by the nature and amount of conflict that occurred in the distant past.

1. **Percent of history spent in state of conflict:** percent of time (in years) spent in a state of conflict as defined by KOSIMO (to include crises, violent crises, and wars). Note: percent of time in conflict spans the years in training data ONLY. Source: *KOSIMO data project*, Pfetsch and Rohloff (2000).
2. **Infant Mortality Rate:** (1975-1997): Number of deaths of children under 1 year of age per 1,000 live births. Source: *U.S. Bureau of the Census, International Database* (www.census.gov/ipc/www).
3. **Youth Bulge** (1975-1997): Ratio of population aged 15-29 to those aged 30-54. Source: *US Bureau of the Census, International Data Base* (www.census.gov/ipc/www).
4. **Caloric Intake** (1975-1997): Estimate of the average number of calories consumed per person, per day. Source: Food and Agriculture Organization of the United Nations (<http://apps.fao.org>).
5. **GDP per capita** (1975-1998): Annual gross domestic product per person measured in constant 1998 US dollars. Source: World Bank (1999). *World Development Indicators*
6. **Political Rights Index** (1975-1998): Measure of rights to participate meaningfully in the political process (same scaling as for Civil Liberties Index). Source: *Freedom House* (www.freedomhouse.org).

Figure 3. Original ACT Study Data

1.5 Data Added for ACT II

7. **Life Expectancy** (1975-1997): Average life expectancy (males and females combined)
Source: *US Bureau of the Census, International Data Base* (www.census.gov/ipc/www).

8. **Civil Liberties index** (1975-1998): Measure of the freedom of country's people "to develop views, institutions, and personal autonomy apart from the state." Seven point ordinal scale with 1=free, 7=not free. Source: *Freedom House* (www.freedomhouse.org).

9. **Trade Openness** (1975-1998): Value of a country's total imports and exports as a percent of GDP per capita. Source: *PENN World Tables* (1975-1992); *1999 World Bank Development Indicators* (1993-1998).

10. **Democracy** (1975-1998): Measure of degree of democracy; ranges from -01 (least democratic) to 10 (most democratic). Sources: *Polity98* project (Gurr and Jagers 1995; Gleditsch and Ward 1997; <http://kleditsch.socsci.gla.ac.uk/Polity.html>); (see also Marshall and Jagers n.d. for a recent update).

11. **Religious Diversity** (1975-1999): Largest religious group in country as a percent of total population. Sources: *CIA World Fact Book*; *Country Indicators of Foreign Policy Project (CIFP)*; Ellingsen (1996); *Handbook of the Nations*; *Britannica Book of the Year*; *Demographic Yearbook*.

12. **Ethnic Diversity** (1975-1999): Largest ethnic group in country as a percent of total population. Sources: same sources used to measure religious diversity above.

Figure 4. Data Added for ACT II

1.6 Expanding the Definition of Instability

Figure 5 describes how the definition of instability was broadened in ACT II vis-à-vis ACT. The ACT study used armed conflicts that involved battle fatalities as the proxy measure of instability used to validate the macro-structural factors as relevant contributors to instability. These data were acquired from the Conflict Data Project at Uppsala University. The Uppsala Data Project tracks all violent conflicts that have transpired around the world, and in which at least 25 battle fatalities occurred, over the period 1989-1997 (it has since been updated through 1999). Though it proved to be adequate given the purpose of the ACT study, this data set was not sufficient to meet the requirements for ACT II. First, its temporal limitation (1989-1999) prohibits its use in validating a 15-year forecast. Second, it contains information only on *violent* intra- and inter-state conflicts that are rare events relative to the number of less violent yet still serious inter- and intrastate interactions. If left to fester in the absence of remedial intervention, it is these less violent, but conflictual interactions that have the potential to escalate into far more serious state crises and wars. As such, the inclusion of these nonviolent crises in a framework that seeks to anticipate serious state crises and instabilities is a desirable, if not crucial, element in its potential to achieve a measure of success.

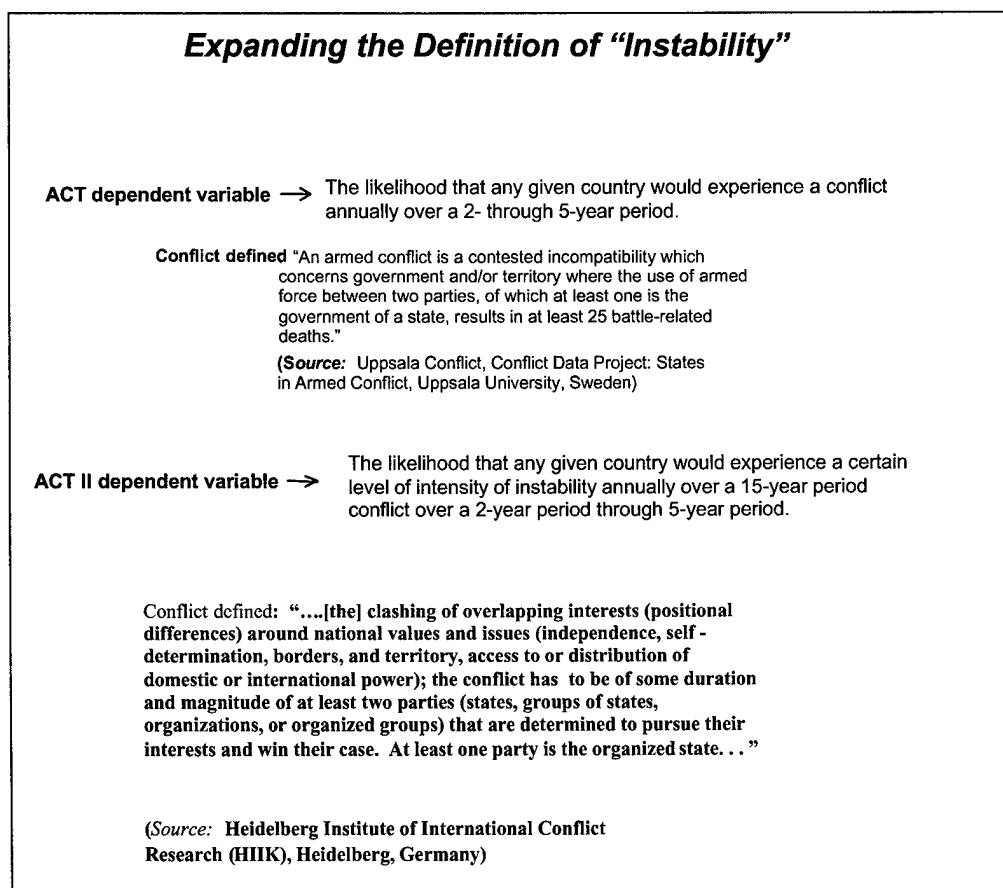


Figure 5. Expanding the Definition of Instability

It is for these reasons that an alternative data set was used in ACT II. The KOSIMO project at the Heidelberg Institute of International Conflict Research in Germany embraces a deliberately vague definition of *conflict*--essentially, any incompatibility between at least one state and another, or between at least one state and some non-state group that lasts for a while and is somewhat intense (see Figure 5 for the project's formal definition).

The KOSIMO project constructed a comprehensive database of all conflicts occurring between 1945 and 1999, regardless of type (e.g., interstate wars, intrastate wars, foreign policy crises, etc.) and intensity. Many of the violent conflicts were drawn from well-known data collections such as the Correlates of War (COW) project at the University of Michigan (recently moved to Penn State University) and the International Crisis Behavior (ICB) project at the University of Maryland among others. However, KOSIMO also allows for nonviolent conflicts specifically because they have the potential to escalate into violent conflicts.

The KOSIMO project identified 74 mostly nonviolent *crises*, 121 *violent crises*, and 61 *wars* over the period 1975-1999. Figure 5 defines and provides examples of each of the three conflict types. Using the data from KOSIMO, a score (ranging from 1 to 4) was assigned for each country-year in the database according to the maximum level or intensity of conflict the country experienced in that year. If the most intense conflict in which a country engaged was a war, either as an initiator or as a defender, then it receives a score of 4 for that year. It receives a score of 3 if it experienced, at most, a violent crisis, a 2 if it experienced no more than a nonviolent crisis, and a 1 if it experienced none of these three conflict event types. This four-category ordinal level scale is the proxy measure of instability used to validate the factors described above as relevant contributors to instability.

Based on the historical relationship between country macro-structurals and the proxy index of instability as uncovered in the training data, the Fuzzy Analysis of Statistical Evidence (FASE) algorithm used to analyze these factors computes the likelihood that each of these four conflict events will occur annually in each country in the test set. These likelihood measures are aggregated, and an expected intensity level of instability is derived for each country by applying the following decision rules:

1. If the combined probabilities of conflict types 1 and 2 occurring in a given country is greater than 67 percent, then the expectation is that the country will experience *no* or *low* intensity instability.
2. If the combined probabilities of conflict types 2 and 3 occurring in a given country is greater the 67 percent, then the exception is that the country will experience a *moderate* intensity instability.
3. If the combined probabilities of conflict types 3 and 4 occurring in a given country are greater the 67 percent, then the exception is that the country will experience a *high* intensity instability.
4. If more than one of the first three decision rules allies to a particular country-year forecast, select the one that reflects the highest intensity level of instability.

1.7 Three Levels of Instability Intensity

<u>Instability Levels</u>	<u>Conflict Type</u>	<u>Examples</u>	<u>Definition</u>
High intensity	4 – War	WWII, Gulf War, Six Days War	Systematic, collective use of force by regular troops
	3- Violent crisis	Northern Ireland, Basque separatists, ethnic conflict in Bosnia	Sporadic, irregular use of force, “war-in-sight” crises
Moderate intensity	2- Crisis	Russian Federation vs Ukraine over possession of strategic weapons	Mostly nonviolent
None/Low intensity	1- None		

Figure 6. Three Levels of Instability Intensity

5. If none of these decision rules applies, that is, if the probability of any one of the three instability intensity levels is roughly equally distributed across the possible conflict event types, then we are *uncertain* about that country’s likelihood of instability. (An *uncertain* forecast is neither correct nor incorrect as far as the performance of the forecasting algorithm is concerned. In any given year, approximately 10-15 percent of all predictions made are of an *uncertain* nature. Historically, about 50 percent of these cases ultimately experience a conflict type 2, 3, or 4 in that year.)

6. A forecast is correct if, and only if, a country experiences, as its maximum intensity level of conflict, one of the two conflict type events covered by the forecasted level of instability intensity, as defined in Decision Rules 1-3.

In addition to the ease with which they facilitate the presentation and interpretation of results, these decision rules were developed because they also facilitate an arguably fair, and somewhat conservative, test of the forecasting method’s performance. The sixth decision rule, for instance, articulates the conditions under which a forecast will be considered correct. If the algorithm correctly forecasts that a country will be unstable, but does not identify the correct *intensity level* of that instability, then the forecast is considered incorrect. For example, if the algorithm were to forecast that Country A in 1991 had an 86 percent probability of experiencing a moderate intensity instability (e.g., either conflict type 2 or 3), and the country actually experienced a war

that year (conflict type 4) then that forecast would be considered a miss and therefore, incorrect. Of course, other decision rules may be equally plausible.

In the ACT study (CAA-SR-99-4), analysts evaluated several different analytical techniques, including logistic regression, classification and regression trees (CART), temporal decision trees, and neural networks to determine how well each could identify or “learn” patterns in the relationships between country macro-structurals and the likelihood of country instability. The technique that consistently demonstrated an ability to accurately distinguish those countries that would and those that would not subsequently experience an instability, given the values of country macro-structurals, was one that was developed by the Center for Army Analysis specifically for these types of classification problems. FASE is a nonlinear, nonparametric pattern classification algorithm. It is a hybrid technique that incorporates theoretical elements from statistics, fuzzy logic, and possibility theory. FASE is used in the ACT II study to validate a 15-year forecast. A detailed description of FASE can be found in the ACT report.

1.8 Forecasting Method

Fuzzy Analysis of Statistical Evidence (FASE) Model

- **Nonlinear, nonparametric, pattern classification algorithm.**
- **Hybrid method, incorporating elements from statistics, fuzzy logic, and possibility theory.**
- **Developed by CAA specifically for ACT-related applications.**
- **Professionally peer-reviewed; patent pending**

Chen, YuanYan. 2000. “Fuzzy Analysis of Statistical Evidence.”
IEEE Transactions on Fuzzy Systems 8(6):796-799

Figure 7. Forecasting Method

Several enhancements were made to FASE between the ACT and ACT II studies. For example, the early version of FASE used in ACT could accommodate only limited dependent variables with two classes (e.g., stable/unstable, conflict/no conflict). The revised methodology can predict to multiple classes on the dependent variable. Second, the early version of FASE developed predictions of country instability using a combination of the *possibility measure* and

certainty factor which, though mathematically rigorous, are new and unconventional likelihood measures. The new FASE, while still based on the possibility scores and certainty factors, facilitates the transformation of this inference of classification into probabilities that are more familiar and more easily interpreted. Finally, the new FASE incorporates control variables to facilitate the development of more nuanced models of country instability. If the statistical patterns of conflict vary significantly by a particular independent variable--for instance, by geographic region or level of economic development--then this independent variable can be used as a control variable in the analysis.

1.9 Enhancements Made to FASE Model for ACT II

- * The dependent variable extended from binary classes to accommodate multiple classes.
- * Transformed the inference of classification into probability measures for forecast prediction.
- * Added control variable to incorporate different statistical patterns.

Figure 8. Enhancements Made to FASE Model for ACT II

It may be instructive to illustrate the application of FASE by example. Consider the following illustration: Let D be some dependent variable with four classes (D_1, D_2, D_3, D_4). A set of attributes, A_1, A_2, A_3 , which can take a range of values, are thought to be correlated with D and available in the form of a historical database. Given a set of observations on A_1, A_2, A_3 , for some transaction (or case) T , evaluated in a historical context, what is the likelihood of each of the four classes of D ? This question is analogous to predicting the correct instability intensity level from a set of country macro-structural attributes. Using FASE, we approach the problem as follows. First, we divide the data set into training and test sets using spatial or temporal rules and then either randomly or by selection. Second, we split the data for each attribute in the training set by each class label of D and estimate the class probability distributions for each attribute. For discrete variables, the probability is estimated by the relative frequency in each category. For continuous variables, we estimate the probability density function using an average shifted histogram (ASH), kernel method, or other suitable density estimator. These probability distributions are the likelihood templates against which observations on the attributes in the test set are to be evaluated.

1.10 FASE: Possibility Aggregation Example

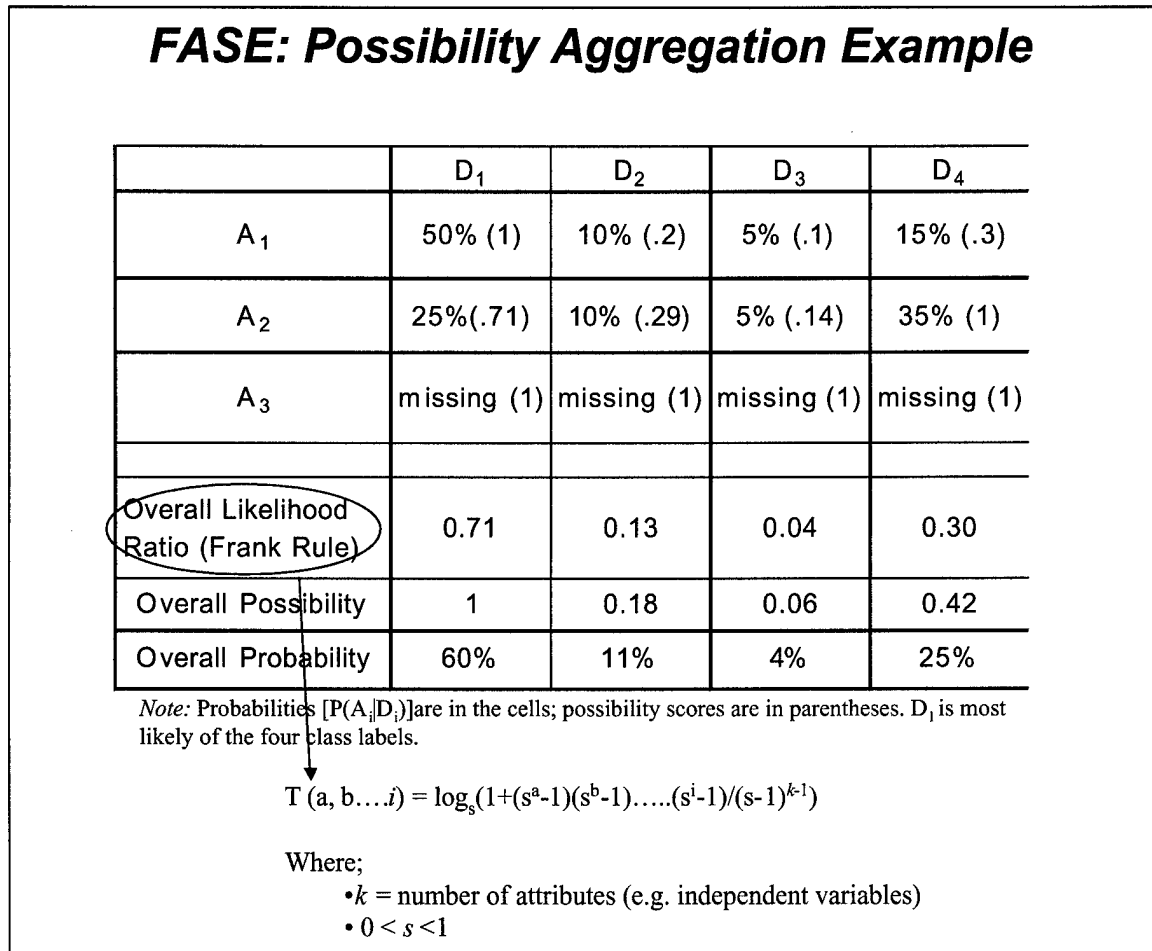


Figure 9. FASE: Possibility Aggregation Example

Third, using data in the test set, we evaluate how well the algorithm can classify on each of the class labels on D . To do that, for any observation on an attribute in the test set, we calculate the likelihood ratio across the class labels on D , based on the patterns observed in the class probability distributions from the training set. Suppose those probabilities are distributed across the class labels as they appear in the example in Figure 9. Historically, in this example, transactions with values on the order of magnitude comparable to those for A_1 and A_2 have been associated with the outcome D_1 50 percent and 25 percent of the time, respectively (note the data on A_3 are completely missing for purposes of illustration).

If A_1 and A_2 are not independent (and this is the assumption here), then we cannot aggregate the evidence across them to compute the likelihood of the class labels without violating the assumptions of probability theory. Therefore, in the fourth step, we normalize the likelihood ratios for each attribute into a possibility measure, using the most likely class label as the base.

The possibility measures appear in each cell in parentheses. Thus, by definition, the most likely class label for any observed attribute value will always have a possibility score of 1. A possibility score of 1 is also given in those instances in which the data on an attribute for some transaction is missing. Since, in such instances, no class label is any more or less likely than any other, this ensures that missing data are treated as such. The possibility measure is not neatly interpretable; one must consider the possibility and its conjugate (the *belief* measure) together. A possibility of 1 does not represent complete certainty about an outcome as it does in probability, but is rather only an imprecise indication of our belief in that outcome, *relative to the other possibilities*; however, the possibilities do reflect ordinal properties consistent with probability theory.

In the fifth step, we aggregate the possibility measures across the attributes for each class label on *D* using the fuzzy set t-norm known as the *Frank Rule*.

$$T(a, b, \dots, i) = \log_s(1 + (s^a - 1)(s^b - 1) \dots (s^i - 1) / (s - 1)^{k-1});$$

where *k* is the number of attributes and *s* is an adjustment parameter that is set close to 0 if our independent variables are highly correlated and 1 if they are independent (*s* is set to .01 here). We apply the Frank Rule to the possibility scores for the attributes on each class label. This produces overall likelihood ratios, which, again, are normalized into overall possibility measures for each class label. The overall possibility measure of a class label indicates that class label's likelihood given a vector of observed (or forecasted) attribute values. For ease of interpretation, these overall possibility scores for each class on the dependent variable can be transformed back into probability measures by straightforward normalization. Having applied this process to the example in Figure 9, we see that *D1*, with a 60 percent probability, is the most likely outcome.

1.11 Model Development, Training, and Validation

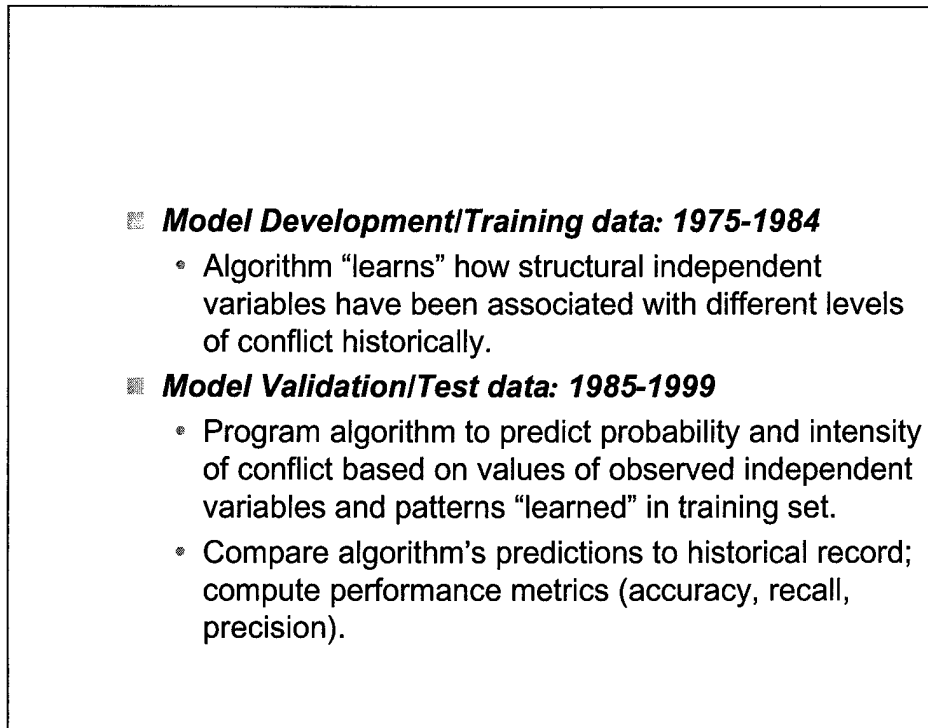


Figure 10. Model Development, Training, and Validation

FASE was used in ACT II to validate a 15-year global forecast of country instability. To do so, a split-sample validation design was used. The data for the 10-year period 1975-1984 are used as the training set. The FASE procedure was applied to the data in this training period to “learn” how different configurations and levels of country macro-structurals have been associated with different levels of instability. Then, using the data on country macro-structurals *only* for the period 1985-1999 (the test set), FASE classified the countries by their expected intensity levels of instability based on the historical patterns. We then compare how FASE classified each country with actual occurrences over the period 1985-1999 (as defined by KOSIMO) and compute standard performance metrics. The performance metrics reveal how well FASE can learn the existing patterns and how robust the patterns are through time.

1.12 Model Development, Training, and Validation - Colombia

Possibility scores and forecast for **Colombia (1992)** using patterns observed in data from 1975-1984.

<i>Variable</i>	<i>Observed value</i>	<i>Pos(None)</i>	<i>Pos(crisis)</i>	<i>Pos(violent crisis)</i>	<i>Pos(war)</i>
Caloric intake	2443	1	0.74	0.53	0.81
Infant mortality rate	33.00	0.71	1	0.51	0.19
Political rights index	2	0.73	1	0.52	0.4
GDP per capita	2007.29	0.83	0.8	0.86	1
Civil Liberties index	4	0.99	0.94	1	0.53
Life Expectancy	68	0.62	1	0.55	0.22
Youth Bulge	1.12	0.75	1	0.41	0.86
Religious Diversity	95	0.82	1	0.92	0.7
Ethnic Diversity	58	1	0.97	0.56	0.43
Democracy	9	1	0.8	0.82	0.16
Trade Openness	35	0.67	1	0.89	1
% of history spent in state of conflict (1975-1984)	70%	0.14	0.78	0.7	1
Overall Likelihood Ratio (Frank Rule)		0.11	0.54	0.17	0.03
Overall possibility		0.20	1	0.31	0.06
Overall probability		13%	64%	20%	4%
Predicted level of instability:		84% likelihood of conflict type 2 or 3 (moderate intensity)			
Conflict type that occurred:		Violent crisis (Type 3)			
Accuracy of forecast:		Correct prediction			

Figure 11. Model Development, Training, and Validation - Colombia

Figures 11 and 12 display output of this validation analysis for Colombia in 1992 and Kyrgyzstan in 1994. These forecasts were generated from patterns FASE identified over the period 1975-1984 and therefore represent 8 and 10-year validation forecasts, respectively. Figures 10 and 11 are designed to resemble the notional example in Figure 8. The second column in each table displays the observed values for each of the macro-structural factors for that country in the year indicated. The possibility scores associated with each of the four class (or conflict type) outcomes are displayed in the cells.

The results in Figure 11 suggest that, based on the macro-structural factors Colombia exhibited in 1992 and the decision rules articulated above, we would expect a moderate intensity instability (conflict type 2 or 3) to occur with an 84 percent probability. Colombia was engaged in a violent crisis (conflict type 3) in 1992--a counterinsurgency against the Revolutionary Armed Forces of Colombia (FARC) that began in 1964 and persists today--and nothing more serious, so we would regard this forecast as a correct prediction.

1.13 Model Development, Training, and Validation - Kyrgyzstan

Possibility scores and forecast for **Kyrgyzstan (1994)** using patterns observed in data from 1975-1984.

Variable	Observed value	Pos(None)	Pos(crisis)	Pos(violent crisis)	Pos(war)
Caloric intake	2322	0.84	0.88	0.82	1
Infant mortality rate	67	0.48	0.26	1	0.84
Political rights index	4	0.52	0.37	1	0.35
GDP per capita	840.72	0.79	0.76	0.86	1
Civil Liberties index	3	0.78	0.78	1	0.38
Life Expectancy	65	0.8	0.43	1	0.5
Youth Bulge	1.05	0.48	1	0.44	0.64
Religious Diversity	75	1	0.82	0.4	0.56
Ethnic Diversity	52	0.45	0.53	0.47	1
Democracy	6	0.61	0.75	0.078	1
Trade Openness	74	1	0.87	0.87	0.89
% of history spent in state of conflict (1975-1984)	missing	1	1	1	1
Overall Likelihood Ratio (Frank Rule)		0.19	0.12	0.05	0.17
Overall possibility		1	0.64	0.25	0.88
Overall probability		36%	23%	9%	32%
Predicted level of instability:		Uncertain (no aggregation combination >67% probability)			
Conflict type that occurred:		None (Type 1)			
Accuracy of forecast:		Neither correct nor incorrect			

Figure 12. Model Development, Training, and Validation - Kyrgyzstan

Kyrgyzstan is an interesting case because it does not even exist in the period covered by the training set. Also, data were available on Kyrgyzstan only for half the test set years (1991-1999). Therefore, its *percent of history in state of conflict* variable, which is calculated based only on years in the training set, is completely missing. KOSIMO does not record a conflict for Kyrgyzstan in 1994 or, for that matter, for any other year between 1991 and 1999. The FASE analysis does indicate that based on Kyrgyzstan's macro-structurals in 1994, a conflict type 1 (none) is most likely (36 percent probability). However, the probabilities on no two adjacent conflict levels breach the 67 percent threshold. So, by the strict decision rules governing this analysis, we could conclude that we are uncertain about what level of instability Kyrgyzstan was likely to experience in 1994, a forecast that would be considered neither correct nor incorrect from an overall performance perspective.

1.14 5- to 15-Year Validation of FASE Model

Figure 13 displays the average 5- to 15-year validation performance results calculated in 5-year increments over all 159 countries. Three performance metrics are computed, and their formulas are displayed in Figure 12. *Overall accuracy* measures the ability of the algorithm to correctly distinguish between those countries that do and those that do not experience some specified intensity level of instability. The *recall* score pertains to the ability of the algorithm to correctly forecast or classify on the element of interest--in this case, the correct conflict type. *Precision* refers to the ability of the algorithm to classify without producing a large number of false positives (e.g., conflicts or instabilities that are forecast to occur but do not). Taken together, the *recall* and *precision* scores are generally the most important and, ideally, both should be as large as possible.

Global Validation (159 countries)				
Test Set Years	# of years in test set	Overall Accuracy	Recall	Precision
		$\frac{\text{\# of correct predictions}}{\text{\# of predictions made}}$	$\frac{\text{\# of correctly predicted conflicts}}{\text{\# of conflicts that occurred}}$	$\frac{\text{\# of correctly predicted conflicts}}{\text{\# of conflicts predicted to occur}}$
1995-99	5	90%	88%	82%
1990-99	10	84%	77%	77%
1985-99	15	82%	77%	70%

Figure 13. 5- to 15-Year Validation of FASE Model

Intuitively, we might expect the performance of a method for forecasting conflict and instability to degrade over time, which is what we see in Figure 13. All the performance metrics trend downward over the 15-year forecast horizon. Nevertheless, the performance metrics are

promising. The FASE Model correctly identified and classified 88 percent of all the conflicts that occurred in the first 5-year forecast horizon and did so without producing many false positives (82 percent of the cases predicted by the model to be conflicts were *not* false positives). The average overall accuracy and recall scores remain above 80 percent and 75 percent, respectively, over the entire 15-year validation forecast horizon.

1.15 15-Year Validation of FASE Model

Figure 14 displays the performance metrics broken out by area of responsibility (AOR). Those results suggest that the FASE Model does very well in predicting variations in levels of instability for countries within the United States Army Pacific Command (USPACOM), United States Army Central Command (USCENTCOM), and United States Army Southern Command (USSOUTHCOM) AORs. Well over two-thirds of all the conflicts in which countries in those AORs participated over the period 1985-1999 were correctly identified and classified by the level of intensity at which they occurred.

Average Validation Scores by Command (1985-1999)			
Command	Accuracy	Recall	Precision
USSOUTHCOM	83%	74%	62%
USPACOM	86%	77%	80%
USEUCOM	79%	65%	68%
USCENTCOM	68%	79%	68%
USACOM	83%	46%	100%

Approach: Model Development and Validation

Figure 14. 15-Year Validation of FASE Model

The results are somewhat less impressive for countries in the United States Army Atlantic Command (USACOM) and United States Army European Command (USEUCOM). USACOM includes only three countries--Canada, Mexico, and the United States--and the model did not correctly predict the level of instability Mexico experienced as a result of the Chiapas Rebellion (1994 through 1999). This accounts for the preponderance of the poor performance witnessed within the USACOM AOR. In the case of USEUCOM, the European countries such as Britain,

France, and Balkan nations experienced more conflict than might be expected, given the configuration of their macro-structural indicators, whereas those African countries that fall within the AOR experienced less conflict than might be expected, given their structural performance. The end result is a combination of relatively poor recall and poor precision.

1.16 Summary

- ACT II provides a defensible analytical approach for developing long term, global, “first cut” forecasts of country instability.
- Amenable to scenario development and “what if” drills.
- Provides an assist to strategic planners.
- ACT II methodology is being applied to help determine where best to place Army prepositioning equipment sets

Figure 15. Summary

In summary, the ACT II study extended an earlier methodology to successfully validate a 15-year global forecast of levels of country instability with good performance results. The forecasts of country instability are generated from the patterns exhibited by country macro-structurals. Because macro-structurals trend in gradual, largely predictable directions, they can be forecast into the future with a reasonable degree of expected accuracy. This suggests the utility of the approach for conducting consistent, rigorous, “first-cut” forecasts of future country instabilities in every major country in the world. These forecasts would be amenable to scenario development and “what if” analyses since the forecasts of country macro-structurals could be readily adjusted to account for new information or changes in assumptions.

It is partly for these reasons that in May 2000, the Center for Army Analysis was asked by the ODCSOPS War Plans Division to apply the ACT II methodology in support of two logistics studies for the Quadrennial Defense Review (QDR): *Enabling Strategic Responsiveness (ESR)* and *Deployment Optimization Research in Tools and Operations (DORITO)*. The ESR and DORITO studies, taken together, will develop and apply a methodology to, among other things, determine where best to preposition Army equipment in support of the Chief of Staff of the

Army (CSA's) deployment goals. Of considerable concern to ESR and DORITO sponsors is the question of where challenges to US national security interests might occur in the future.

Analyzing Complex Threats for Operations and Readiness (ACTOR) will apply the ACT II methodology to generate 15-year (fiscal year (FY) 2001-15) global forecasts of country instability. In so doing, it will seek to identify those countries that are likely to possess in the future not only the willingness and opportunity to challenge US national security interests, but also the capacity to do so.

(THIS PAGE INTENTIONALLY LEFT BLANK)

APPENDIX A PROJECT CONTRIBUTORS

1. PROJECT TEAM

a. Project Director

Dr. Sean O'Brien, Resource Analysis Division

b. Team Members

Dr. Yuan-Yuan Chen

Ms. Kumud Mathur

Mr. Mark Ricks

c. Other Contributors

Ms. Doris Futrell

Ms. Tina Davis

Mr. Eric Vardac

Mr. John Warren

2. PRODUCT REVIEWERS

Dr. Ralph E. Johnson, Quality Assurance

Ms. Nancy Lawrence, Publications Center

3. EXTERNAL CONTRIBUTORS

Dr. Alan R. Goldman, National Ground Intelligence Center

Ms. Valery Guralnik, Army High Performance Computing Research Center, University of Minnesota

Mr. Gerry Halbert, National Ground Intelligence Center

Dr. George Karypis, Army High Performance Computing Research Center, University of Minnesota

Mr. Scott Mingleford, National Ground Intelligence Center

(THIS PAGE INTENTIONALLY LEFT BLANK)

APPENDIX B REQUEST FOR ANALYTICAL SUPPORT

P *Performing Division:* RA *Account Number:* 99167

A *Tasking:* Verbal *Mode (Contract-Yes/No):* No

R *Acronym:* ACT-2

T
Title: Analysis of Complex Threats 2

1 *Start Date:* 20-Sep-99 *Estimated Completion Date:* 30-Sep-00
Requestor/Sponsor (i.e., DCSOPS): DCSOPS, DCSINT *Sponsor Division:* SSW, ZA
Resource Estimates: a. *Estimated PSM:* 48 b. *Estimated Funds:* \$0.00
c. *Models to be Used:* ACT/. SADE

Description/Abstract:

DCSOPS and DCSINT requested CAA to use the Analysis of Complex Threats methodology for use in the Total Army Analysis - 2009 (TAA-09) and the next Quadrennial Defense Review (QDR) to (1) conduct and validate a 10-year global forecast for the years from 2000 through 2010; (2) broaden the scope of the country instability analysis to include additional independent and dependent variables; (3) explore the integration of ACT and SADE analyses; (4) continue the examination of available methods and the development/refinement of new methods for country instability assessment and analysis.

Study Director/POC Signature: Original Signed

Phone#:

Study Director/POC:

If this Request is for an External Project expected to consume 6 PSM or more, Part 2 Information is Not Required. See Chap 3 of the Project Directors' Guide for preparation of a Formal Project Directive.

Background:

P

A

R *Scope:*

T

2

Issues:

Milestones:

Signatures *Division Chief Signature:* Original Signed and Dated

Date:

Division Chief Concurrence: Mr. Steven Siegel

Sponsor Signature: Original Signed and Dated

Date:

Sponsor Concurrence (COL/DA Div Chief/GO/SES):

(THIS PAGE INTENTIONALLY LEFT BLANK)

CAA-R-01-41